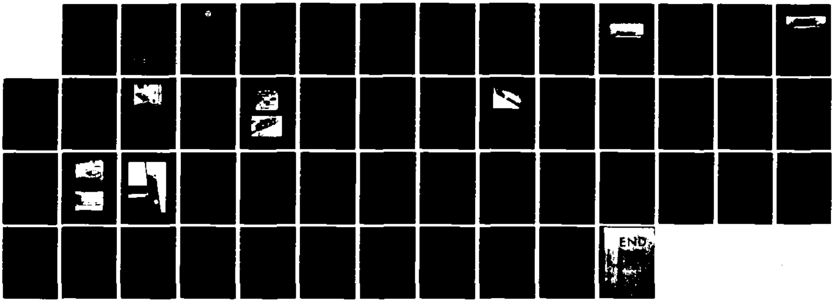
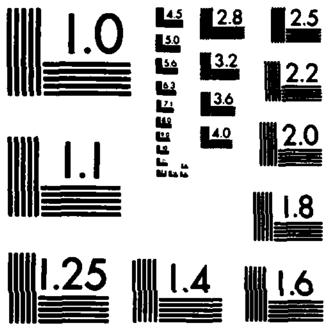
AD-A132 602 PORTABLE LIFE SUPPORT STRETCHER UNIT (PLSSU) ENVIRONMENTAL TESTS: PREPRODUCTION MODEL(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA G W ROWLEY ET AL. JUN 82 1/1

UNCLASSIFIED NOSC/TR-797 F/G 6/12 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(13)

NOSC TR 797

AD-A132 602

NOSC TR 797

Technical Report 797

PORTABLE LIFE SUPPORT STRETCHER UNIT (PLSSU) ENVIRONMENTAL TESTS: PREPRODUCTION MODEL

G. W. Rowley
R. W. Kataoka

June 1982

Final Report: October 1980—September 1981

Prepared for
Naval Medical Research and Development Command
(Code 45)

Approved for public release; distribution unlimited

NOSC

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

JM PATTON, CAPT, USN
Commander

HL BLOOD
Technical Director

ADMINISTRATIVE INFORMATION

This technical report describes work performed under program element 64771N, project M0933-PN (NOSC 512-FA23), between 1 October 1980 and 30 September 1981 for the Naval Medical Research and Development Command, Code 45, Bethesda MD 20014. It summarizes the environmental tests performed on a preproduction Portable Life Support Stretcher Unit during the period 17 June to 17 September 1981 in the Environmental Test Branch's facility. The principal investigators of this work are G.W. Rowley (Code 9431), under the direction of R.H. Chalmers, Head, Environmental Test Branch (Code 9431), and R.W. Kataoka (Code 5143), under the direction of W.T. Rasmussen, Head, Bioengineering Branch (Code 5143).

Released by
W.A. Wright, Head
Test and Evaluation Division

L.W. Bivens, Head
Biological Sciences Division

Under authority of
I.P. Lemaire, Head
Ocean Engineering Department

H.O. Porter, Head
Biosciences Department

UNIT CONVERSIONS

1 inch = 25.4 mm
1 lb_f = 4.45 N

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NOSC Technical Report 797 (TR 797)	2. GOVT ACCESSION NO.: AD-A132 602
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): PORTABLE LIFE SUPPORT STRETCHER UNIT (PLSSU) ENVIRONMENTAL TESTS: PREPRODUCTION MODEL	5. TYPE OF REPORT & PERIOD COVERED: Final October 1980–September 1981
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): G.W. Rowley, R.W. Kataoka	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Ocean Systems Center, San Diego CA 92152	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 64771N, M0933-PN (NOSC 512-FA23)
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Medical Research and Development Command (Code 45), Bethesda MD 20014	12. REPORT DATE: June 1982
	13. NUMBER OF PAGES: 48
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Portable Life Support Stretcher Unit (PLSSU)
Preproduction testing
Structural strength
Aircraft environment (helicopter, fixed wing)
Vibration resistance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A preproduction Portable Life Support Stretcher Unit (PLSSU) was subjected to a series of environmental tests, including conditions simulating aircraft (helicopter and fixed wing) environments. The various fittings of the PLSSU were found to have sufficient strength for their intended uses. The main structure showed minor deficiencies in integrity, in both design and fabrication, but is considered to have passed the environmental tests despite some damage. Minor preproduction improvements are recommended in structural reinforcements, fittings, and attachments.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

OBJECTIVE

Subject a preproduction Portable Life Support Stretcher Unit (PLSSU) to a specific series of environmental tests. Determine whether this model of the PLSSU is suitable for production and service use. Describe any improvements that should be made.

RESULTS

1. The various fittings of the PLSSU were found to have sufficient strength for their intended uses.

2. The main structure showed minor deficiencies in integrity, in both design and weld fabrication.

3. The nuts attaching certain fittings drifted loose easily under the influence of vibration.

4. The PLSSU responds readily to input vibration of approximately 15-20 Hz.

5. The detent-type drawer latches provide excellent retention for the drawers.

6. The PLSSU was damaged, but not disabled, by the structural integrity test, and could have remained in emergency service afterwards.

RECOMMENDATIONS

1. Before production, make minor improvements in structural reinforcements, as well as in fittings and attachments.

2. For reasons of strength, do not grind away structural welds.

3. Consider the modified PLSSU acceptable for service use as regards environmental conditions.

CONTENTS

CONTENTS (Continued)

FIGURES

SECTION 1: INTRODUCTION

1.1 SCOPE

The purpose of the Portable Life Support Stretcher Unit (PLSSU) project is to develop a standard unit to carry medical equipment to support a patient during the transfer phase of medical evacuation. The unit will be used aboard ships and military vehicles, such as helicopters and ambulances, to transfer patients.

In this phase of development, 10 preproduction units were fabricated for evaluation. This technical report describes the environmental tests performed on one of these units. The testing was intended as a technical evaluation to qualify the PLSSU design for service use. The tests simulate the worst-case environment of the transfer vehicle. The tests include static load (proof tests), vibration, and structural integrity.

The remainder of the present section describes the background of the PLSSU. Section 2 describes the preproduction version of the unit. The environmental tests and results are reported in section 3. Section 4 is a discussion of test results. Section 5 contains conclusions and recommendations. The references are in section 6, while appendix A lists equipment used and appendix B contains sample vibration plots.

1.2 BACKGROUND

1.2.1 Operational Need

Military medical personnel are often required to transfer patients between primary and definitive care centers. Medical supplies and equipment must be gathered together and be accessible for use by the transporting personnel. Current transfer equipment does not include a unit on which needed equipment can be carried and quickly used. A method is needed for carrying medical supplies and equipment to maintain the patient's condition during

transfer. This method should be compatible with all the various military vehicles used for transfer.

1.2.2 Operational Concepts

The Portable Life Support Stretcher Unit (PLSSU) is a self-contained patient and medical equipment carrier that is fully compatible with military aircraft and vehicles used in medical transfers. The PLSSU converts utility aircraft and other vehicles used in carrying stretcher patients into equipped Medevac units. Removing the PLSSU just as quickly returns the vehicle to utility use. The PLSSU is designed so that all supplies are readily accessible for emergency treatment during the transfer.

The benefits of the PLSSU include the following: (1) provides a versatile compact container which can be equipped with supplies necessary to maintain a patient during transfer; (2) allows patient and equipment to move as one unit; (3) provides a configuration that is compatible with standard canvas litter rack equipment encountered in military helicopters and ambulances; and (4) provides accessibility to all supplies during the transfer.

1.2.3 Testing

The PLSSU is compatible with all helicopter litter rack equipment, with Medevac elevators aboard ship, and with military and civilian ambulance litter-securing equipment. Preproduction models of the PLSSU are being tested aboard LHA-class ships (this class has facilities for a 300-bed hospital and four operating rooms). The unit is also currently being tested as a patient receiving and transporting bed at the Navy Regional Medical Center, San Diego.

A prototype PLSSU was technically evaluated (ref 1) for static load, vibration, and structural integrity. The result of those tests led to design recommendations that were incorporated into the preproduction units subsequently produced for limited service evaluation. One of the preproduction units was selected for the present environmental tests.

1. NOSC Environmental Test Branch, Several Tests on Portable Life Support Stretcher Unit (PLSSU), 20 September 1979.

SECTION 2: DESCRIPTION

The PLSSU is a medical equipment and supply carrier to which a patient carrier can be attached. The modular design allows patient carriers such as a standard canvas litter, a Stokes litter, a backboard (see fig 1), or a specially designed bed-height pallet to be secured.

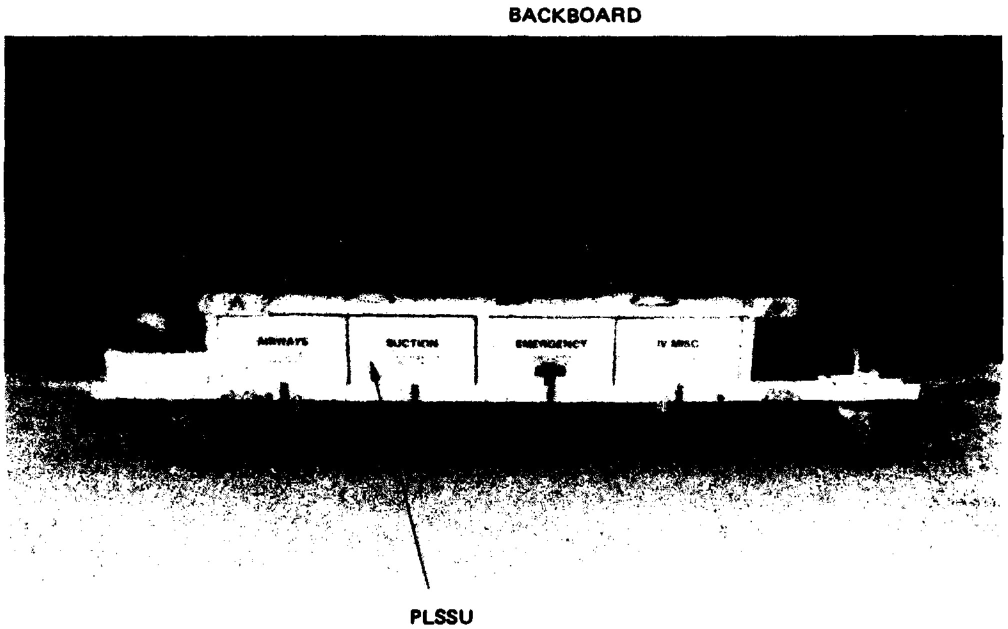


Figure 1. PLSSU with backboard.

The unit is 92 inches long, 22 inches wide, and 16 inches high without a patient carrier, and weighs approximately 164 pounds with equipment and supplies. The handles at each end of the unit are also dimensionally the same as the standard canvas litter. This configuration is similar in dimensions and weight to a standard canvas litter with patient. Thus the PLSSU may be installed in any military evacuation vehicle with modification to standard litter rack spacings, hoists, or securing equipment designed for the canvas litter.

The equipment and supplies selected for use on the unit allow it to function as a portable, self-contained, self-powered crash cart while transporting a patient. Four drawers for equipment and supplies are accessible from either side and may be completely removed. The equipment and supplies are arranged in order of priority for emergency procedures. Airways and resuscitation equipment are located in the drawer nearest the head of the patient. Suction equipment, medicines, blood-pressure cuff, stethoscope, and intravenous supplies are located in the other drawers.

SECTION 3: TEST RESULTS

3.1 TEST PROGRAM

Few military guidelines are available for the environmental testing of medical equipment. The PLSSU tests were based on recommendations from the USAF School of Aerospace Medicine (ref 2), which has experience and a program for testing medical equipment for use aboard fixed-wing aircraft; the Environmental Test Branch, NOSC, which has experience testing equipment for use aboard aircraft and ships; and the Bioengineering Branch, NOSC, which has experience in the use of medical equipment aboard ships. The tests conducted on the PLSSU were designed for the worst-case environment that the unit would experience, which is transportation in a helicopter. These tests exceeded shipboard environmental requirements.

The tests were sequenced in order of increasing difficulty to extract the maximum amount of information about the PLSSU. The unit was inspected before the test program to locate any existing damage or faults. It was examined again after each individual test. The testing began with a series of proof tests, followed by vibration tests and the static load tests.

3.2 PRETEST INSPECTION

The basic structure of the PLSSU is a welded aluminum square-tube framework consisting of two main beams with wooden carrying handles at each end; six vertical columns or members, three above each main beam; two upper beams, parallel to the main beams; and six horizontal crossmembers (these parts are identified in figure 2). All joints are butt joints and were welded around all four sides. The weld beads were then ground away on all corners facing the inner spaces where the four drawers were to be, as well as on the outer faces. This apparently was intended to leave some weld material inside the tube and/or between butted surfaces, while also leaving clearance for the drawers and providing an attractively smooth appearance.

---

2. USAF School of Aerospace Medicine ltr 3865/psa, 28 June 1979.

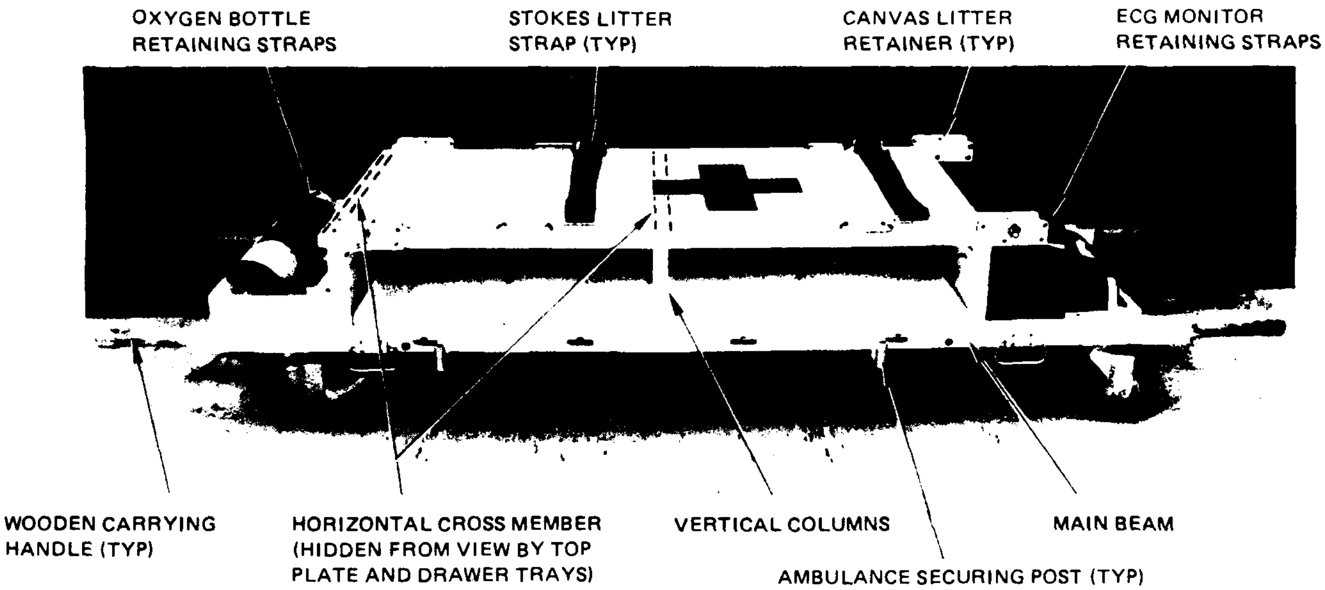


Figure 2. Basic structure and parts.

Before the testing program was begun, the PLSSU was examined for obvious damage and workmanship faults. The only areas of concern found were two incomplete weld joints. They were on the lower, drawer-facing corners of two diagonally opposite end columns, where white paint covered or filled what appeared to be narrow cracks or open spaces. It was impossible to determine whether any weld material was concealed under the paint without damaging the joints in the process.

3.3 PROOF TESTS

The proof test series was applied to try the pull strength of the various small parts and fittings attached to the PLSSU by methods other than welding. These included such items as straps, ambulance posts, and wooden handles held in place by screws, nuts, rivets, or geometry. The forces applied were double those expected in service use.

The tests were accomplished by anchoring the PLSSU to the floor of the work area and applying the required pull by hand (relatively small forces) or

with a chain hoist anchored to a nearby immovable object. The force was measured on a scale attached to the part being tested. (Descriptions of the actual equipment used can be found in the list of equipment in appendix A.)

Eleven different types of small parts and fittings were tested. These parts and the loads applied to them are listed in table 1. It was not always possible to apply the exact desired force, so the actual forces are also shown in the table. Figure 3 illustrates performance of a typical proof test.

All of the small parts and fittings were found to have sufficient strength. None of the 20 tests produced damage or degradation of any sort.

Some observations were made while testing the defibrillator and oxygen bottle retaining straps. On the preproduction PLSSU, these are secured by 2-inch-wide Velcro pads. Initial doubts about the Velcro having adequate fastening strength were dispelled by its demonstrated performance.

Velcro fasteners are meant to be opened by the operator peeling the two pieces apart in direct tension. For the fasteners to open by themselves under load, they would have to pull apart in shear. The tests performed on the PLSSU fasteners produced such a shearing force.

The Velcro fastener for one of the oxygen bottles was tested after it had been only lightly tacked together. The test load of 24 lb_f vertically upward was applied not just the required one time, but four times. The Velcro displayed no tendency to work loose. On peeling the fastener loose, the test engineer found that the load had instead served to set the interlocking fibers more firmly.

The Velcro fastener of an oxygen bottle strap was also tested. The load was again 24 lb_f applied horizontally. The entire Velcro area was put into contact and pressed firmly to seat the fibers. The load force then applied was slowly increased to 60 lb_f before the fastener started to creep. It did not fail suddenly. The rate of creep, although slow, made itself known by an audible tearing noise. Unfortunately, the benefits of Velcro are compromised

Part	Total Qty on PLSSU	Qty Tested	Req'd Load, lb_f	Direction of Load	Applied Load, lb_f
Canvas litter foot retaining ferrule	8	1	200	Horizontal	205
Canvas litter locking pin	4	1	200	Vertical upward	220
Wooden handle (fig 3)	4	2	200	Horizontal lateral	2 @ 200
Wooden handle	4	2	200	Vertical upward	1 @ 220 1 @ 230
Carrying handles on top of PLSSU	4	1	200	Horizontal	200
Carrying handles on top of PLSSU	4	1	200	Vertical upward	230
Ambulance securing post	2	1	400	Horizontal lateral outward	420
Ambulance securing post	2	1	400	Horizontal longitudinal	420
Oxygen rack	1	1	48	Horizontal outward	70
Oxygen rack	1	1	48	Vertical upward	55
Underside tiedown strap and hook	4	2	400	Horizontal @ 45°	1 @ 410 1 @ 415
Drawer wing lock	8	2	15	Horizontally outward	2 @ 20
Strap assembly for oxygen bottles	4	1	24	Vertical upward	24
Strap assembly for oxygen bottles	4	1	24	Horizontal	60
Strap assembly for defibrillator	2	1	40	Upward @ 45° from horizontal	2 @ 40
Strap assembly for Stokes litter	2	1	240	Vertical upward	270

Table 1. Proof tests.

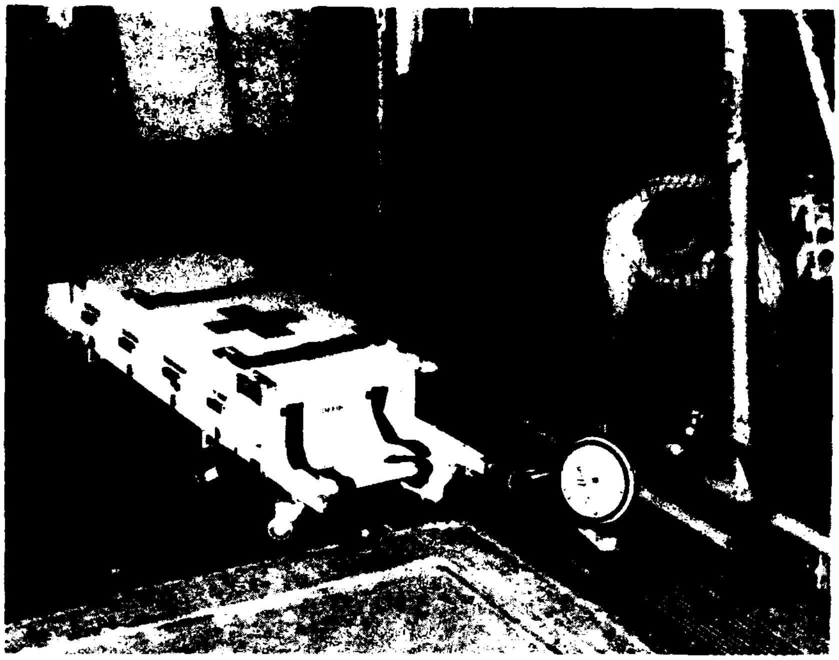


Figure 3. Typical proof test configuration. 200-lb force being applied horizontally to a wooden handle.

by the present strap design on the PLSSU, which prevents the Velcro area from being put into proper contact (see paragraph 3.4.2 below).

3.4 VIBRATION TESTS

3.4.1 General

The PLSSU was subjected to a series of four vibration tests to investigate its behavior under conditions it might encounter in service inside an ambulance, airplane, or helicopter. The actual vibration requirements are listed in the USAFSAM Test and Evaluation Planning Guide for Evacuation Equipment (ref 3), section 3.3.1.5.1, paragraphs (f) and (g). These call for a swept-frequency, sinusodidal input vibration to be applied to the test PLSSU in each of three perpendicular axes in turn (in fact, only two axes were tested, as will be explained). The vibration was to have a constant displacement of 0.10 inch (double amplitude) from 5 to 22 Hz, and a constant 2.5-g

3. USAF School of Aerospace Medicine, Test and Evaluation Planning Guide for Aeromedical Evacuation Equipment, by Clinical Sciences Division, Biomedical Systems Branch, 1 February 1978.

acceleration from 22 to 500 Hz. The frequency sweep was to be completed from 5 to 500 to 5 Hz in 15 minutes. Duration of each test was to be 75 minutes.

Two test configurations were chosen to represent the conditions of actual use of the PLSSU. One configuration was with the PLSSU sitting on its wheels, secured in place by the underside tie-down straps, and with a canvas litter attached; the other was with the PLSSU suspended by its handles from a helicopter hook mounting, and carrying a Stokes litter.

To perform this vibration test on an item as large as the PLSSU, an electrodynamic shaker and a specially designed rigid fixture were needed. The electrodynamic shaker is the device that produces the motion. It operates like a huge speaker, producing mechanical vibration under the influence of an oscillating electric current. The fixture served as an apparatus in which to mount the PLSSU in either of the two test configurations, and through which to conduct the vibration to the PLSSU. For vertical vibration, an adapter for attaching the fixture to the electrodynamic shaker was necessary; for horizontal motion, a sliding table was needed for carrying the weight of the fixture and the PLSSU.

These items are shown in figure 4. The shaker is the cylindrical chest-high object in the lower center of the photograph. The inverted-pyramid webbed structure above it is the adapter for vertical vibration. Atop the adapter is the bed of the 7-foot-long fixture with a stiffening truss structure attached. The PLSSU is inside the fixture, with a Stokes litter on top. In the foreground is the sliding table that was used later for the horizontal vibration motion.

The vibration was produced and controlled by a series of electronic equipments sensing the motion of a transducer (an accelerometer) mounted on the test fixture. Other similar transducers were located at strategic points on the PLSSU to pick up motion information, which was tape-recorded during a sweep of frequency. These transducers are visible most readily in figure 5.

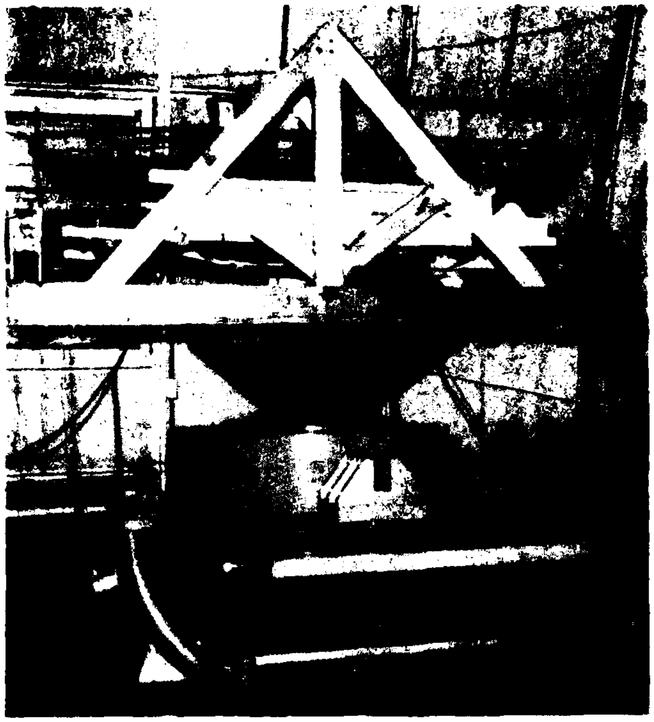


Figure 4. Vertical vibration test. PLSSU suspended by carrying handles. Note Stokes litter.

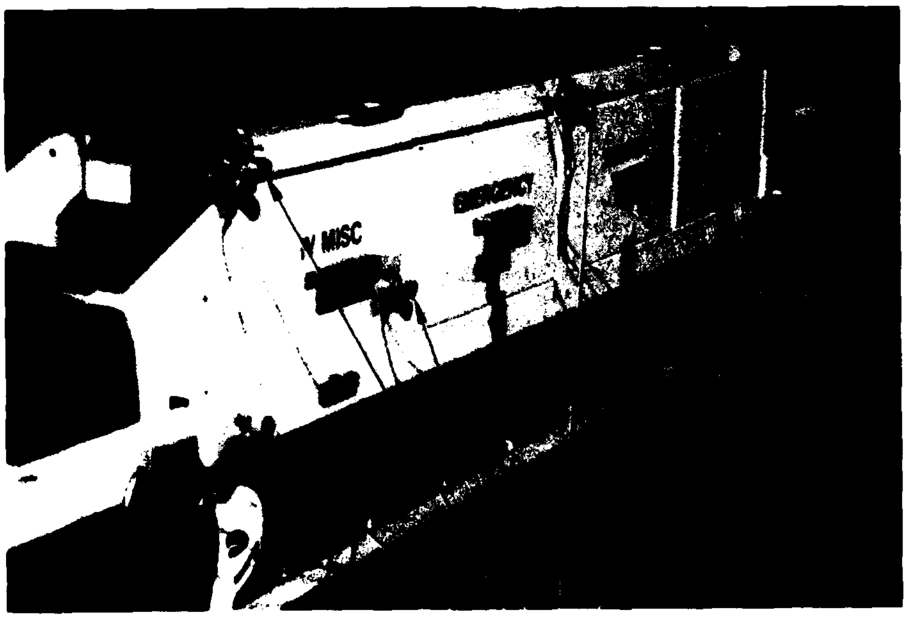


Figure 5. Horizontal vibration. PLSSU on wheels, with canvas litter attached.

The vibration was applied in two of the three possible axes. These were the vertical, and the lateral horizontal. Longitudinal horizontal vibration was omitted because the test equipment was not large enough to make a test in that orientation possible. The design of the PLSSU is such that it is much more rigid in the longitudinal direction than in the other two axes. Thus the loss of information from omitting that axis of vibration was minor.

In each test, mass was added to the attached litter to correspond to a large patient of 250 lb. It was distributed in a manner approximating the form of the human body.

The PLSSU should not be suspended from the helicopter hooks (i.e., by the handles) with a patient aboard. It was found in the evaluation of the prototype PLSSU (ref 1) that its structure failed as a result of vibration while thus suspended. The preproduction PLSSU had these joints reinforced with edgewelded plates. The vibration test with hook suspension in this test program was beyond the requirements of service use and was done only for safety and informational purposes.

3.4.2 Pretest Inspection

Before the PLSSU was placed in the vibration fixture, it was inspected thoroughly for any existing damage. None was found.

The defibrillator was next installed in its tray. It was found that the retaining strap that passes over the defibrillator CRT was about 1 inch too short for complete contact of the Velcro pads.

Additional difficulties were discovered when the two oxygen bottles were installed in their dual tray. The retaining straps did not fit as well as they could, for several reasons. The cylinders were supplied in canvas covers, each with a carrying handle and an accessory pocket. The bulk of these covers and the dimensions of the tray made it impossible for the cylinders to be oriented in the same direction; that is, base-to-base or neck-to-neck.

Most of the interference was at the base end and was in large part due to the cover pockets, which are located near the base.

The covered cylinders will fit in the dual tray if they are oppositely oriented; i.e., neck-to-base. This may, however, be awkward for the corpsman, who would have to reorient his oxygen hose when changing from one bottle to the other, change hands with the required tools, or move bodily.

If the canvas bottle covers are removed, the bare bottles will go into the tray easily in the same orientation. However, the straps at the base ends now interfere in such a manner that they cannot be fastened straight. They must be crossed in an "X" to fasten, which means that only about one-third or one-half the available Velcro pad is in use. This, of course, compromises the good results demonstrated with the Velcro straps during the proof tests.

With or without the covers, the straps that retain the necks of the cylinders overlap too far for efficient use of the Velcro pads. Only about one-quarter of the Velcro overlaps when the straps are snug.

These various weaknesses could be remedied by making the dual tray about 1/4 inch wider, and by extending the Velcro area of the four oxygen cylinder straps. Only those areas on the four straps that anchor to the sides of the tray should be extended, with an increase of about 1 inch toward the anchored ends being the optimum. Nothing would be improved by making any of the straps longer.

When the PLSSU was installed in its vibration fixture, a further problem became evident. The nylon tiedown straps mounted on the underside were found to be too narrow and slender for the clasps on the hook assemblies to which they attach. When the strap ends are pulled to tighten them and fix the PLSSU to the floor, the straps tend to fold over double within the clasp and jam. The clasp must then be released, the strap worked flat again, and another attempt made.

3.4.3 Vertical Vibration on Wheels

The first vibration direction investigated was the vertical, with the PLSSU on its wheels, restrained with the tiedown straps, and with the weighted canvas litter in place.

Before the test was half-finished, one of the upper defibrillator attachment straps fell off. The nut on the inside of the vertical panel to which the strap mounting fitting is bolted had worked loose and spun off the single bolt. The other strap was still attached and the Velcro on both fasteners was still firmly engaged.

After the test was completed, inspection showed that the remaining upper defibrillator strap was now loose. The nut was within two or three turns of coming off completely.

These fittings are attached with their heavy sides up, which is gravitationally unstable. A two-screw attachment would eliminate their tendency to turn over and loosen.

A drawer tray end had worked partially loose. Two of the four rivets that attached the tray to the inside face of the main structural beam were missing (see fig 6); the third was standing free of the tray material by about 1/64 inch, and cracks were apparent in the paint around the head of the fourth, which was still flush. The end flange of the drawer tray was gapped away from the face of the structural beam by about 1/32 inch at one end to about 3/32 inch at the other. During manufacture, the tray had been fabricated too short to fit correctly. Installation of the rivets had pulled it flush, but out of shape and so under tension. The vibration had worked it loose and it had returned to equilibrium.

In this direction of vibration, the PLSSU structure was found to be resonant at 20 Hz with an amplification of motion (ratio of response to input acceleration) of 4.0 at the joint of the end posts with the main beams. The structure was relatively isolated at all other frequencies in the spectrum of the test; typical amplifications of motion ranged from 0.3 down to 0.02.

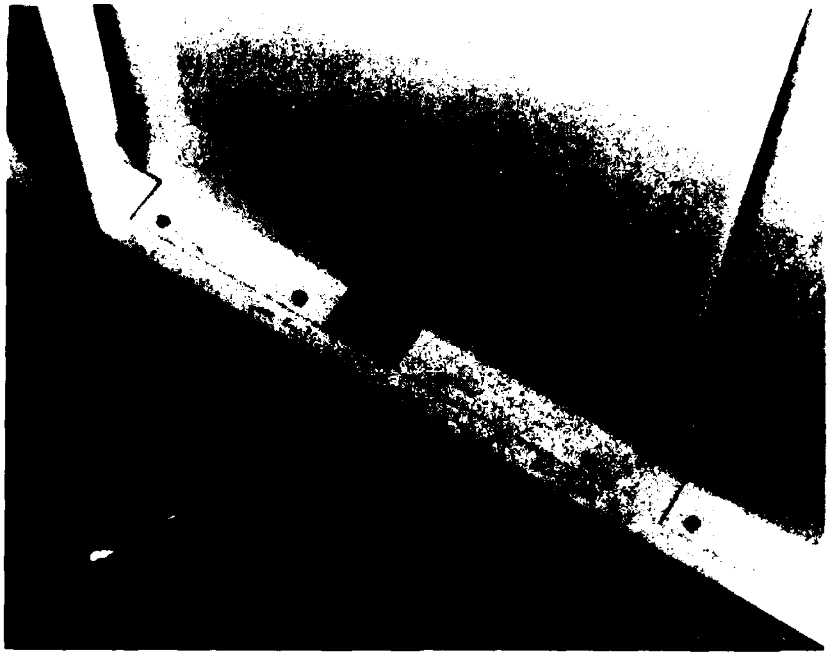


Figure 6. Drawer tray attachment, showing rivet damage after first (vertical) vibration test mode.

The only other significant responses were found in the defibrillator tray. These were at 20, 220, 350, and 470 Hz, with respective amplifications of motion of 1.0, 0.8, 1.2, and 1.4.

3.4.4 Horizontal Vibration on Wheels

Before the start of horizontal vibration, the defibrillator attachment strap fittings were reinstalled and tightened firmly by hand.

Inspection after the completed test revealed no further damage. The drawer tray rivets were as before, and the defibrillator strap fittings were still tight.

Motion sensors attached to various points on the PLSSU provided specific data. The major structural response was at 290 Hz. The amplification of motion varied at different points, from 1.0 to 4.2. An exception was noted in cross-axis (vertical) motion at the center of the upper sides, a response

which measured 13 times the magnitude of the input motion. However, the canvas litter attaches at the corners of the top, where the motion was much less. A frequency of 290 Hz is well above the frequencies of motion generated by ambulances and helicopter rotors.

The PLSSU tended to be isolated at all other frequencies. Visible responses at 20 Hz and 100 Hz, for example, had amplifications of motion of 0.16 maximum and 0.24 maximum, respectively. A vertical response at 100 Hz, again at the center of the top, exhibited a magnitude of 0.4 that of the input. Other responses were yet lower in amplification, down to about 0.008.

At low frequencies, input motion to the test fixture was taken out by fluttering of the castering wheels since the securing straps were too soft to transmit the motion. At higher frequencies, it was observed that the rubber tires sometimes damp the motion, and that sometimes the motion is damped within the PLSSU. At some frequencies, the motion is transmitted. Responses were visually apparent at about 20 Hz and about 100 Hz.

The drawers (which are not part of the PLSSU structure) tended also to resonate at additional frequencies of 120 and 350 Hz at amplifications of motion of 0.8 and 1.0, respectively. This behavior would, however, be affected significantly by the contents of the drawers.

The canvas litter went in and out of the attachment brackets easily, whether loaded or empty. With the prototype this had been a problem because its brackets were narrower and would jam the feet of the litter when it was loaded.

3.4.5 Horizontal Vibration with Handle Suspension

For this test, the canvas litter was replaced with the weighted Stokes litter, which was retained in place with the two sets of straps provided on the PLSSU. The combination was suspended from the helicopter hooks by its wooden handles.

Vibration responses of the PLSSU structure were noted primarily at 10 to 15 Hz (amplification of motion 1.0 to 1.6), around 300 Hz (1.0 to 3.2), and at 500 Hz (0.7 to 1.6). At the top of the center column on each side of the PLSSU, sensors also revealed responses at 120 Hz (amplification 1.0), and cross-axis (vertical) responses at 120, 200 to 230, 250, and at 320 to 360 Hz (respective magnitudes of 1.7, 1.0, 5.8, and 0.6 times that of the horizontal input). This vibration did not produce any new damage nor worsen any existing damage.

3.4.6 Vertical Vibration with Handle Suspension

During preparation for this last vibration test, the PLSSU was hoisted into the vibration fixture by one of the canvas straps used for retaining the Stokes litter. The off-center load thus produced caused the fittings which attach the straps to the top of the PLSSU to pivot about an eighth of a turn, although they did not loosen. This was not an intended use for the strap, but does point up the superiority of two-bolt attachment over the single bolt now in use.

Responses were found in the structure at 20 Hz, with associated amplification of motion of 0.4 to 0.9; at 80 Hz (0.8); 207 Hz (1.0 to 2.5); at several frequencies between 240 and 275 Hz (amplifications from 0.5 through 5.2); and at 340 Hz (0.5 to 1.4). Other vertical responses appeared only at one sensor. These were at higher frequencies; specifically, 355 Hz (1.4) directly above the central column, 488 Hz (0.5) in the main beam at the end column, and 495 Hz (0.3) at the handle. Cross-axis (horizontal) vibration was discovered at several other frequencies, including 140 Hz, with amplitudes of 0.07 to 1.0 times the magnitude of the input, and at several other frequencies, 185, 350, 405, and 500 Hz, all with increases of amplitudes up to 1.6 times. The highest significant amplifications of motion were found in the defibrillator tray: 0.9 at 140 Hz, 4.2 at 207 Hz, 1.6 at 265 Hz, and 1.1 at 340 Hz.

No further damage occurred to the drawer tray that had become loose during the vertical vibration test. Apparently, it had reached its relaxed

position and was in equilibrium, the rivets not being sufficient to retain it in stressed attachment.

Two cracks had formed on the inner (fore-and-aft) faces of the lower main beam joints with the end columns. The entire side of each was broken to and just around the corners. These corners had originally been welded, but all or very nearly all the weld bead appeared to have been ground away to allow clearance for the adjacent drawers to slide. The small reinforcing gussets that were added as a result of structural failure of the prototype PLSSU under these same vibration tests were successful. At this point in the earlier tests, the prototype had suffered much more serious damage.

3.4.7 General Observations Following Vibration Tests

The post-vibration examination was conducted thoroughly to serve also as a pretest inspection for the final series of tests to follow.

The vibration, particularly in the horizontal axis, produced a scratching of the paint finish on the drawer tray upper surface and on the underside of the drawer. This will be normal in service and causes no damage, but the paint is soft enough to scratch easily and the marks will show.

Two of the carrying handles are located on main beams outside the defibrillator tray. The attaching screws pass through the main beams and are nutted on the inside next to the defibrillator. The exposed ends of the screws are sharp and are a finger hazard. A screw about 1/4 inch shorter should be used, and should be retained with a tall nylon-insert locking nut or an acorn nut with a lock washer.

Another finger hazard as a result of poor workmanship was present in the drawer marked "Airways." The overlap joints inside and at the top corners were neither flush nor attached.

The second pair of carrying handles is located on the main beams under the first drawer on the oxygen end of the PLSSU. The nut ends of their lower

retaining screws emerge from the beam next to the end of the flange of the drawer tray. The nuts and lock washers (no plain washers were present) were supported under one side only by the end of the flange. When the nuts were tightened, the bolts were bent, or they were left only partially tightened so that there was no support under half the nut. Either the drawer tray should have a wider flange or a notch in the flange around each bolt; or the nuts should be raised on one or more narrow-width plain washers to clear the flange.

Throughout the PLSSU, there are usually no plain washers under the lock washers. It is preferred technique that there should be, on painted metal surfaces. In some locations, narrow-width plain washers would be required to suit the available clearances.

Each time the helicopter hooks were unlatched and the PLSSU handles lifted out of them, a layer of the rubber pad from the hook unit was left on the wooden handle. This occurred with both the single snap-on hook and the multiple set of hooks on a strap. The rubber bonds tightly to the wood and is difficult to remove. In such cases, there is also less pad left on the hooks for the next use. Note that the PLSSU was left suspended in the hooks overnight (although under its own empty weight only).

At no time during the vibration tests did the drawer latches fail to remain securely in the latched position. These spring-loaded detent latches successfully solved the loosening problem manifested in the prototype.

3.5 STRUCTURAL INTEGRITY TESTS

3.5.1 General

The last set of tests performed on the PLSSU was a series of four static load tests. These were done in both the wheel and the hook-suspension configurations. A mass weighing 720 lb was applied in each configuration, followed by an increase to 1845 lb. These were intended to simulate supporting device loads imposed by the PLSSU with its equipment, normally weighing 160 lb, times

4.5 g acceleration in an aircraft, as well as a similar acceleration load consisting of the PLSSU with a large patient, total normal weight 410 lb.

3.5.2 Wheel Configuration

As the PLSSU sat on its wheels, mass was added to a total of 720 lb. There was no noticeable change in the PLSSU. Additional weights then brought the added load to 1845 lb. The PLSSU sagged 7/8 inch at the center, but the drawers still slid in and out without binding. The tires flattened only slightly.

When the mass was removed, and the PLSSU examined, it was found that one of the cracks previously described in paragraph 3.4.6 (main-beam-and-end-column weld next to the defibrillator tray) had spread a short distance farther around the corners of the column.

3.5.3 Handle Configuration

The PLSSU was suspended by its handles in the fixture previously used for the vibration tests. This gave a greater span for the PLSSU structure to support. With 720 lb in place, the crack on the oxygen end opened farther and extended partially around the corners of the joint.

As more load was added, the cracks grew. One propagated so suddenly as to make an audible tearing sound. The PLSSU sagged several inches but did not break (fig 7). When the load was removed, a permanent sag of about 1 1/4 inches was left in the main beams (fig 8). The drawers still operated without binding. There was no danger of collapse under the static load

3.5.4 Post-Test Inspection

The majority of the bending in the main beams was located at the defibrillator end of the PLSSU, at the end columns.

Damage was present at all six lower main-beam-to-column joints (fig 9). At the defibrillator end, there were three open sides at one corner and one and one-half at the other. At the oxygen end, each corner joint had one open side. The lower center column joints cracked on one side each, one about 1/4 inch long and the other about halfway around a corner, with enough strain to crack the paint.

All six upper joints were also damaged, to a lesser exent than the lower ones. The majority of damage was confined to one side of the joint.

The breaks on all 12 joints started where welds had been ground away to clear the drawers. They continued around to the outside, where the welds had also been ground away for appearance.

Bending of the main beams had pulled out the corner rivets in the defibrillator tray. The tray was still firmly attached, however, with 12 other rivets to hold it.

There was no further damage to the previously loosened drawer tray. Only one of the four reinforcing plates on the lower end joints had given way. At this point in the testing of the prototype PLSSU, two of those joints were completely broken and a third was broken halfway, leaving the upper and lower parts of the PLSSU dangling from each other.

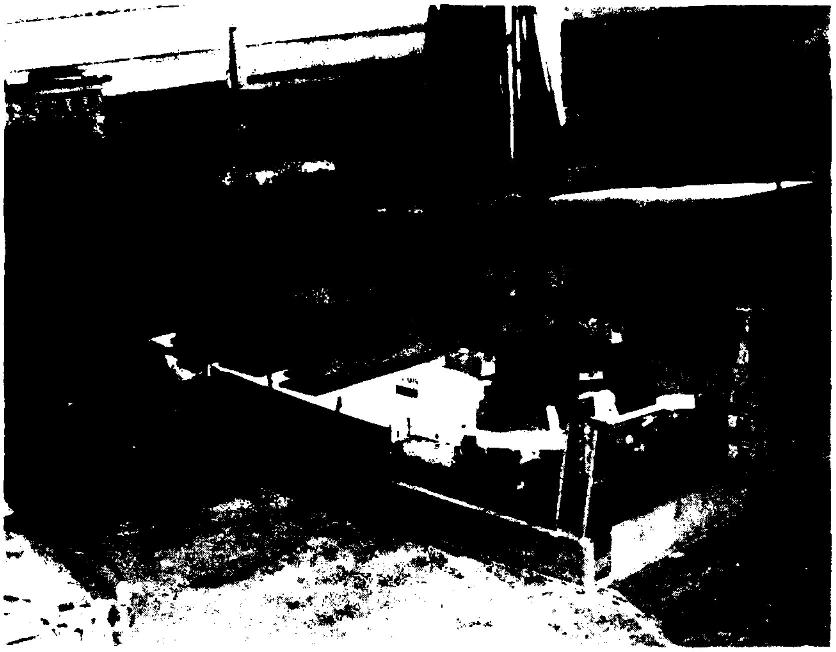


Figure 7. Static load test: 1845 lb_f supported by the wooden handles.

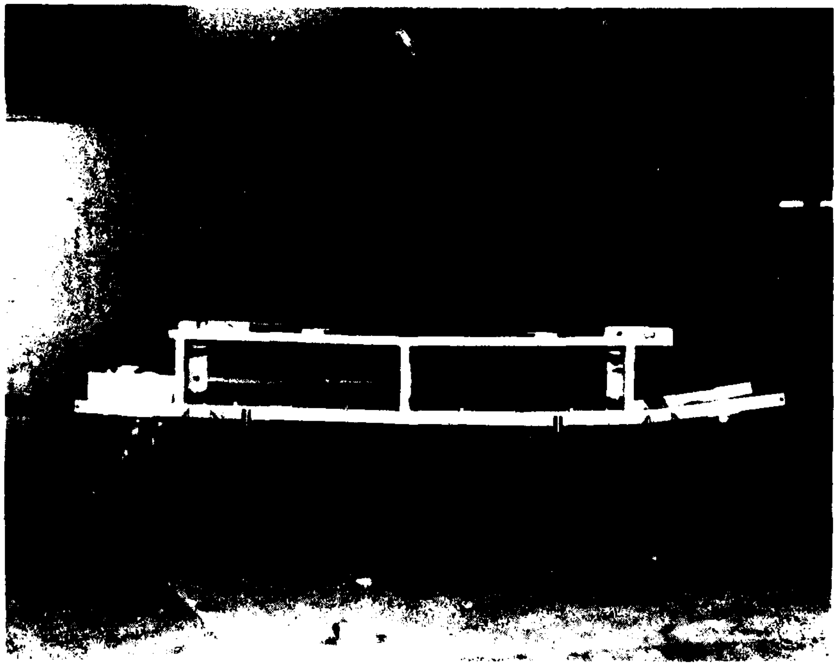


Figure 8. PLSSU after static load. Both main beams were permanently bent. Drawers are removed for clarity.

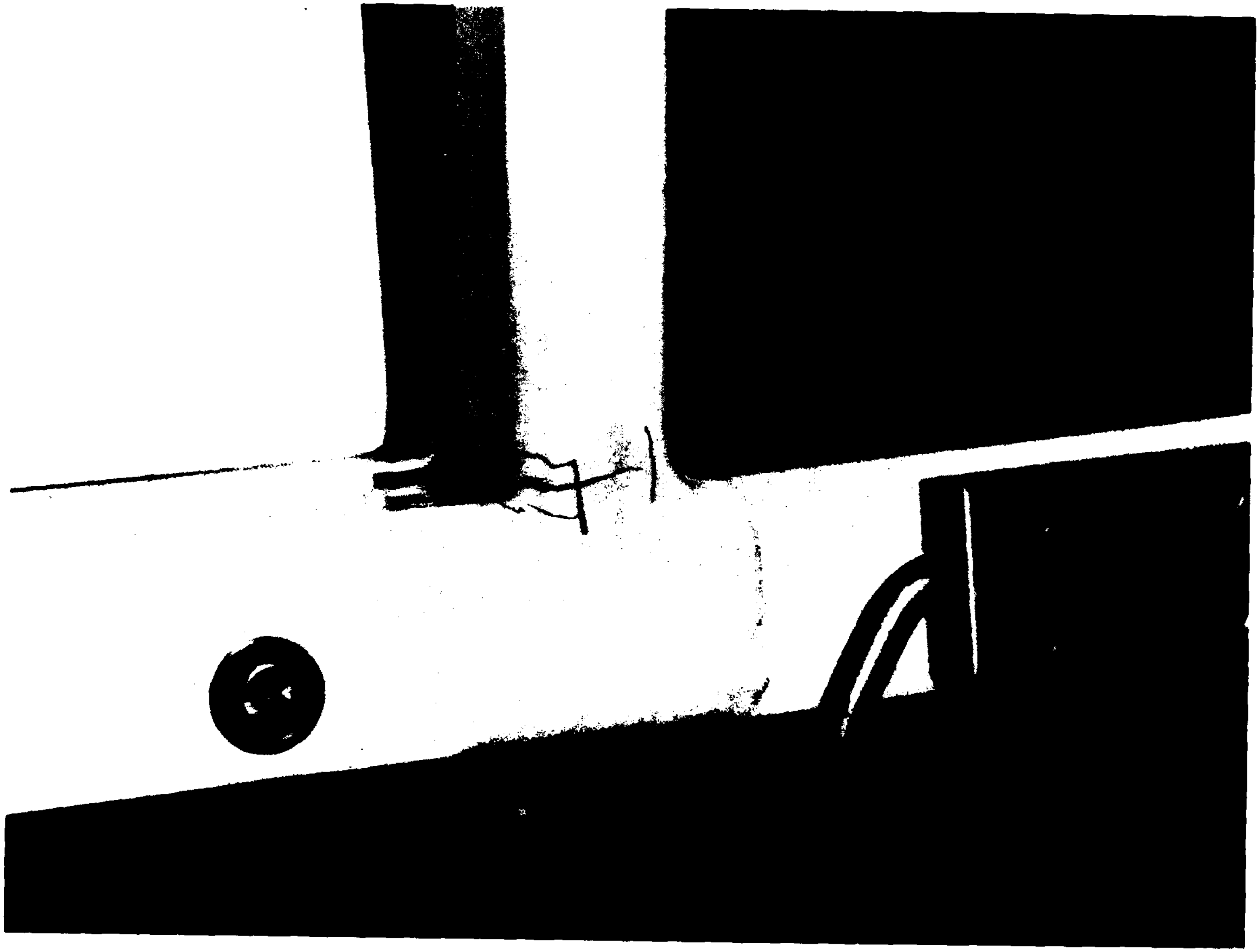


Figure 9. Main-beam-to-column damage after structural integrity tests. Defibrillator end of PLSSU.

SECTION 4: DISCUSSION

During the vibration test, the sheet aluminum defibrillator tray was found to respond noticeably to driving motions at test frequencies above 200 Hz. Responses at 220, 350, and 470 Hz, for example, were excited readily by input in the vertical direction when the PLSSU was vibrated while standing on its wheels. Some of these motions were greater in amplitude than the input motion. When a defibrillator is in place on the tray, such high-frequency response motions are themselves inputs to the defibrillator.

Although the defibrillator has been qualified for aeromedical evacuation aircraft vibration environments (ref 4), its electronic and mechanical parts are not immune to stress and fatigue. The small sizes of those parts means that they are more likely to be susceptible to high-frequency motions than to the response of the PLSSU at 15-20 Hz. Over a period of time, these motions could cause failure of the leads by which electronic parts are supported and attached. A sheet of motion-damping plastic foam placed on or, better, attached to the tray would lower the response frequency (or frequencies) of the tray-foam-defibrillator system far away from the natural frequencies of the defibrillator components. The components should then enjoy a much longer life.

This assumes, of course, that the foam cushion was not so thin as to allow the defibrillator to bottom out, which would produce a shock input. One-half to 1 inch of the appropriate type of foam might well be sufficient.

Throughout the vibration tests, a fundamental mode was observed at about 15 to 20 Hz (depending on the configuration). This was due to simple bending of the main beams. Amplifications of the input motion up to four times (1.6 g or a peak-to-peak displacement of 0.08 inch) were observed.

---

4. USAF School of Aerospace Medicine, Status Report on Medical Material Items Tested and Evaluated for Use in the USAF Aeromedical Evacuation System, by Crew Technology Division, Aeromedical Evacuation Systems Support Crew Production Branch, January 1979.

Motions of this magnitude will be annoying to a patient. There are, however, several reasons for accepting this characteristic.

Foremost is the fact that other provisions are provided for the patient's support in the potentially vibrating conveyances. In fact, suspending the patient-loaded PLSSU from the hooks in a helicopter is warned against in the instructions (see ref 5).

Secondly, a response to motion is a basic characteristic of nature; there is no object in the universe that is totally inflexible. Any modification to the PLSSU to change the fundamental response could succeed only in shifting it to a higher or lower frequency. Even a total redesign, including a change of material, such as to steel instead of aluminum, could not be expected to produce a major change in the frequency.

Furthermore, almost any engineering design is a series of compromises. In the case of the PLSSU, a redesign to stiffen the structure and thus raise the response frequency in a major way would likely either add enough weight that carrying the unit would become difficult or impossible for the corpsmen, or would add so much extra structure that it would no longer fit in the desired space.

It may be possible to make the response frequency quite low by cushioning the PLSSU between the structure and the wheels, or beneath the wheels, through the addition of very soft spring mounts. This approach could filter out motions above several Hz at the expense of considerable additions in complexity and overall height. Such mounts would require that four additional pieces of equipment be carried about. Further complexity would be introduced by adding an analogous system to cover the handle suspension case.

The best overall tactic is to accept the basic PLSSU design as it is, knowing that it may respond in vibrating environments and necessitate removal of the patient from the PLSSU. Further applicable comments are made below.

---

5. NOSC TN 405, Portable Life Support Stretcher Unit (PLSSU): Instruction Manual, revision A, by R.W. Kataoka and J.P. Weir, 20 April 1978.

Note that addition of the gussets, as recommended in paragraph 5.2, section 2, would increase the basic frequency somewhat. An increase will also result from any decrease in the mass on the PLSSU.

Both the vibration and structural integrity tests pointed up the weakness of the welds joining the structural tubes, particularly at the highly stressed junctions of the end columns with the main beams. This weakness derives from the fact that the weld beads in many places were ground away after the welds were completed. This was done on all outboard faces for the sake of appearance, and in the corners facing the drawers to provide clearance for the drawers to slide. Unfortunately, this removes most of the welds. What remains is approximately only the thickness of the thin-wall tubing itself. This remnant is commonly weaker and more brittle than the tubing because of material differences, incomplete penetration, and hurried annealing. It commonly forms a stress riser.

The outside weld beads are actually neither overly large nor unsightly. Existing external welds in other places on the PLSSU are, in fact, not at all noticeable. It would improve the strength of the PLSSU to leave the subject welds as they were formed (sharp edges and abrasive roughnesses should be smoothed).

In the corners of the drawer spaces, there is in fact enough room presently to allow a modest fillet. Further clearance could be readily provided by a small increase in the bend radius of the long corners of the sheet aluminum drawers. The present bend radius appears to be about 1/8 inch. It is suggested that a bend radius no less than 1/4 inch be used.

The structural integrity test resulted in partial failure of several of the structural joints of the PLSSU. However, the structure remained attached at each joint. The PLSSU was not disabled, and could have remained in emergency service in that condition. Had a patient been on the PLSSU during the breakage, he would not have been endangered.

The static load test did not perfectly model the momentary acceleration load felt by an aircraft because of the much longer duration of the load in the laboratory. Each of the two configurations of the test required about an hour to accomplish, as the individual masses were added and removed.

Because of this difference in time span, the static load test constituted overtest under certain conditions. Structures typically do not respond as strongly to input pulses of duration shorter than one-half the natural period as they do to longer ones. In the case of a PLSSU responding at 20 Hz, a gust load shorter than 25 ms should produce minimized response.

The structural integrity test had more validity as a model of longer-span pulses. As the PLSSU is a rather flexible structure, it can be expected to respond with damped vibration. Repeated vibration of sufficient magnitude could cause failure by fatigue just as the (long-duration) static load test caused it by simple stress. This is a further reason for strengthening the susceptible joints by means of gussets in the production configuration.

These remarks indicate the likely behavior of the PLSSU following a load pulse, but they cannot be considered the final word because an actual shock test was not performed.

SECTION 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The PLSSU should be considered to have passed the series of proof tests, as no damage or degradation resulted from any of them.

It should also be considered to have performed successfully through the vibration tests. The welds in the joints where the two cracks formed after the last and most severe vibration test contributed very little to the strength of the PLSSU even before they broke, as they were nearly, or completely, ground away during manufacture. The PLSSU structure was sufficiently intact after the five hours of vibration that it readily could have continued in service.

In addition, the resonances of the PLSSU were mostly at frequencies well above those of any sustained large-amplitude motions likely to be produced by an ambulance or helicopter.

Structural joint breakage did occur as a result of the static load tests. However, none of the joints failed completely. Only one broke on three sides. Had there been a patient on the PLSSU, he would not have been endangered, and the PLSSU could have remained in temporary service. The static load test, however, was not truly representative of all possible 4.5-g momentary loads felt by an aircraft. For practical use, the PLSSU should be considered to have passed the static load test.

5.2 RECOMMENDATIONS

The recommendations presented here are for the correction of minor deficiencies, since no major structural shortcomings were revealed in the tests.

1. A better method should be found or better workmanship employed for making those joints from which the weld beads are later ground away. There is, in fact, enough room to leave some of the drawer-side fillets in place without binding the drawers. The easiest design change to add clearance would be to increase the bend radius of the drawer sides somewhat.

The weld beads on the outside need not be ground completely flush to have a good appearance. An unfinished bead or a neatly smoothed ridge would be much stronger.

2. To strengthen the most heavily stressed of the PLSSU structural joints, and to allow the PLSSU to be picked up occasionally with a patient aboard during an emergency, it is recommended that the end columns be gusseted to the main beams by triangular aluminum plates about 1/4 inch thick. Four such gussets are recommended, one at each corner alongside the oxygen and defibrillator trays. Six-by-12-inch welded gussets would probably not interfere with use of the oxygen or defibrillator.

3. More care should be taken during fabrication to make the drawer trays exactly the right length. Incorrectly prepared trays should be discarded, not installed.

4. Those items that are retained with screws and nuts need improvements in two aspects. Those fittings that have only one bolt or screw should have two. These parts presently can slip in rotation even though the fastener is as tight as possible. A better nut-locking method also should be used. A metal lock nut or a deep lock nut with a nylon insert would probably be the best choices.

5. The tiedown straps for securing the PLSSU to floor fittings should be wider and heavier to fit their hook assemblies. Alternatively, a smaller hook assembly could be used, but this could make a retest necessary.

6. The tray for the pair of oxygen bottles should be made wider by about 1/4 inch. This will allow the corpsman more freedom in orienting, securing, and using the bottles.

7. The Velcro pads on the defibrillator retaining straps and on the center retaining straps for the oxygen bottles should be modified slightly to allow more secure retention of those equipments. Details of the recommended changes can be found in paragraph 3.4.2.

8. A plastic foam cushion should be provided on the defibrillator tray, as discussed in section 4.

9. The carrying-handle screws that protrude into the defibrillator tray should be shortened about 1/4 inch and retained with a nylon-insert lock nut, an acorn nut and lock washer, or some other smooth device.

10. Workmanship on the drawers should be more closely examined before acceptance.

11. The installation of washers and nuts half on and half off the supports should not be tolerated. The land beneath such retentions should either be flat, or sufficient narrow flat washers to clear the raised edge should be used.

12. Flat washers should be used beneath all lock washers or lock nuts, even on metal surfaces. By spreading the force, they allow the nut to be set more tightly and they protect painted finishes.

13. A spray of silicone lubricant applied to the bottoms of the drawers and to the drawer trays would make the drawers slide more easily, even when loaded, and would tend to protect the painted finish. An alternate approach would be to build in strips of Teflon or similar material on the drawer trays. However, the silicone spray is much more rapidly applied.

REFERENCES

1. NOSC Environmental Test Branch, Several Tests on Portable Life Support Stretcher Unit (PLSSU), 20 September 1979.

2. USAF School of Aerospace Medicine ltr 3865/psa, 28 June 1979.

3. USAF School of Aerospace Medicine, Test and Evaluaticn Planning Guide for Aeromedical Evacuation Equipment, by Clinical Sciences Division, Biomedical Systems Branch, 1 February 1978.

4. USAF School of Aerospace Medicine, Status Report on Medical Material Items Tested and Evaluated for Use in the USAF Aeromedical Evacuation System, by Crew Technology Division, Aeromedical Evacuation Systems Support Crew Production Branch, January 1979.

5. NOSC TN 405, Portable Life Support Stretcher Unit (PLSSU): Instruction Manual, revision A, by R.W. Kataoka and J.P. Weir, 20 April 1978.

APPENDIX A
LIST OF EQUIPMENT

PROOF TESTS

Spring scale, Chatillon type 160, 100-lb capacity, 1-lb divisions, no s/n.

Chain hoist, Manning Maxwell & Moore manual "Tugit," model M-1423, 1-ton capacity, no s/n.

Dynamometer (scale), Dillon, 500-lb capacity, 2.5-lb divisions, s/n AN31564.

VIBRATION TEST

Calibration shaker, MB Electronics model EA1500, s/n 111.

Calibration accelerometer, Endevco 2215F, s/n PA69, calibrated 7 April 1981.

Vacuum tube RMS voltmeter, Hewlett-Packard model 400H, s/n 4835.

Audio oscillator, Hewlett-Packard model 200AB, s/n 009-12732.

Audio oscillator, Hewlett-Packard model 202D, s/n 80414.

Vibration test unit, MB Electronics model P11G-30, s/n 288.

Accelerometers, Endevco model 2217E, quantity eight, no s/ns.

Electrodynamic shaker, Calidyne model 177A, s/n 95.

Reaction block, MB Electronics model 3030-33-1, s/n 100-78.

Slip plate, Kimball Industries model 2860, s/n SP6010ST-352.

Power amplifier, MB Electronics model 4120, s/n 114.

Fixture, shaker to PLSSU, design and fabrication by NOSC Code 9331.

Amplifiers, MB Electronics model N400, quantity eight, no s/ns.

Vibration programmer, Unholtz-Dickie Corp oscillator-sweep model OSP-4-R, s/n 113.

Tape recorder, Ampex model FR-1300, s/n 6440110.

X-Y plotter, Moseley "Autograf" model 135, s/n 2321.

Variable electronic filter, Spencer-Kenmore Laboratories, s/n 837-164.

Sine converter, Spectral Dynamics model SD103, s/n 96.

PREVIOUS PAGE IS BLANK

Carrier generator, Spectral Dynamics model SD120, s/n 58.

Tracking filter, Spectral Dynamics model SD122L, s/n 204.

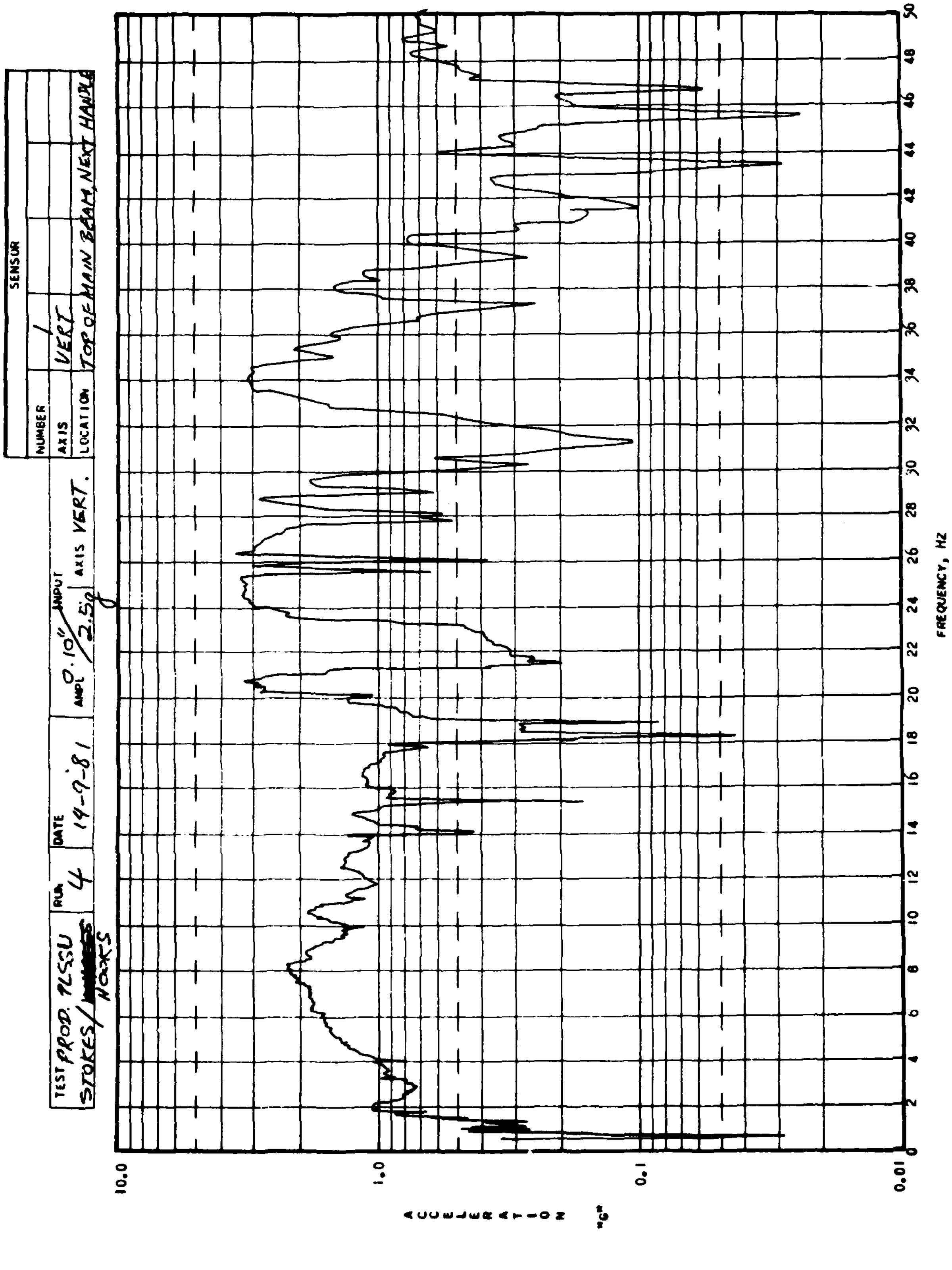
Oscilloscope, Tektronix model 422, s/n 008323.

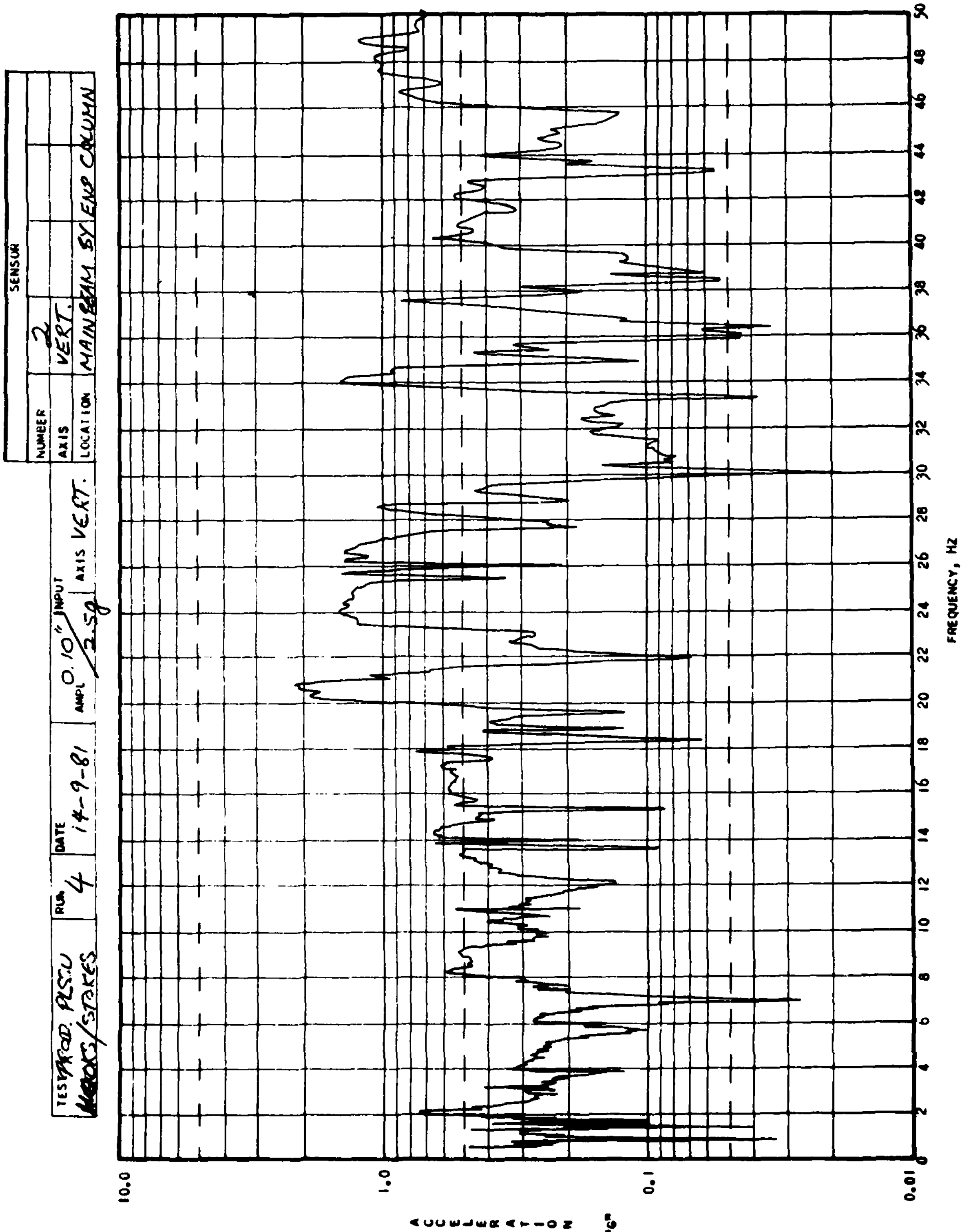
STATIC LOAD TESTS

Balance, Howe, 1000-lb capacity, 1/2-lb divisions, no model or s/n.

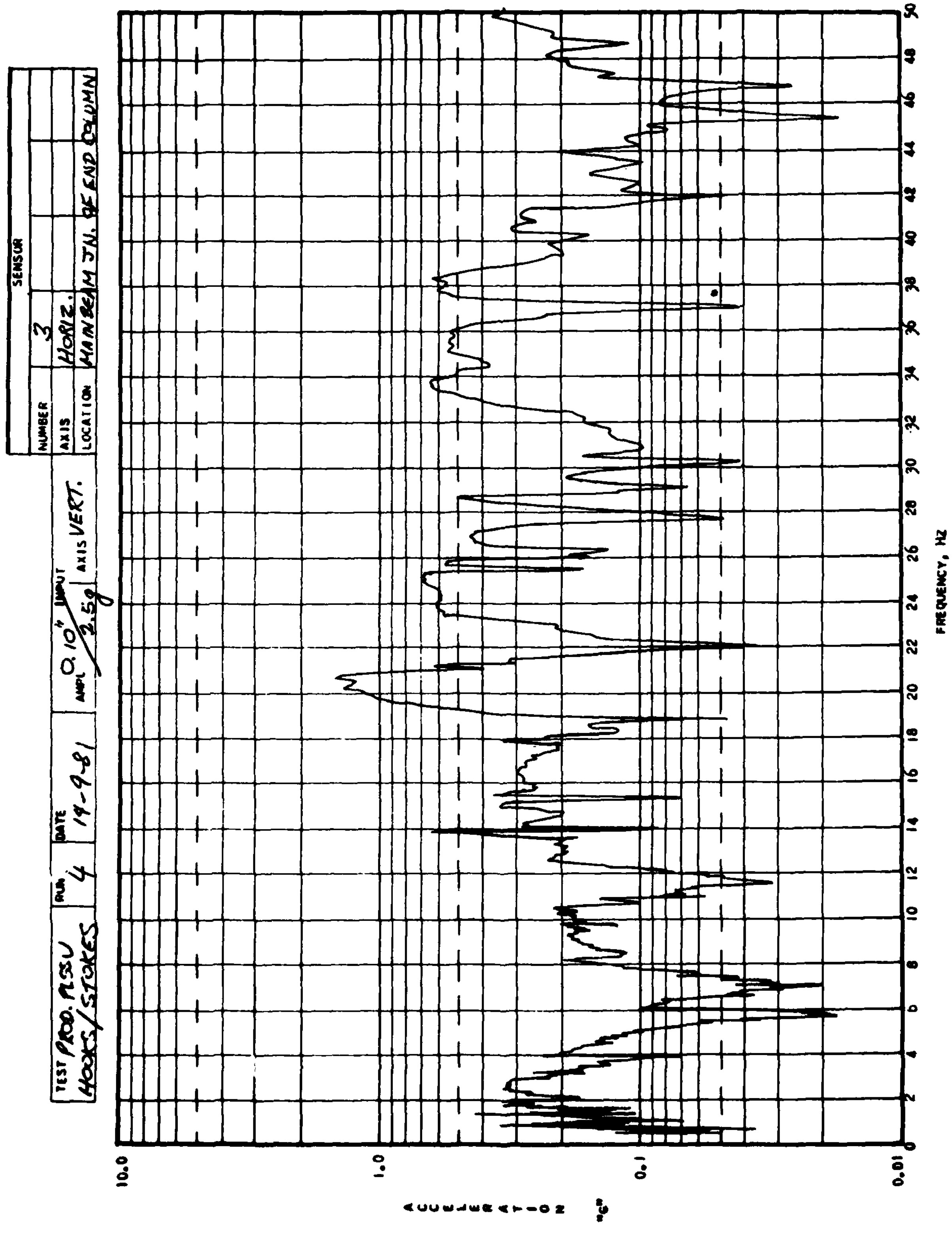
APPENDIX B

SAMPLE VIBRATION SCANS

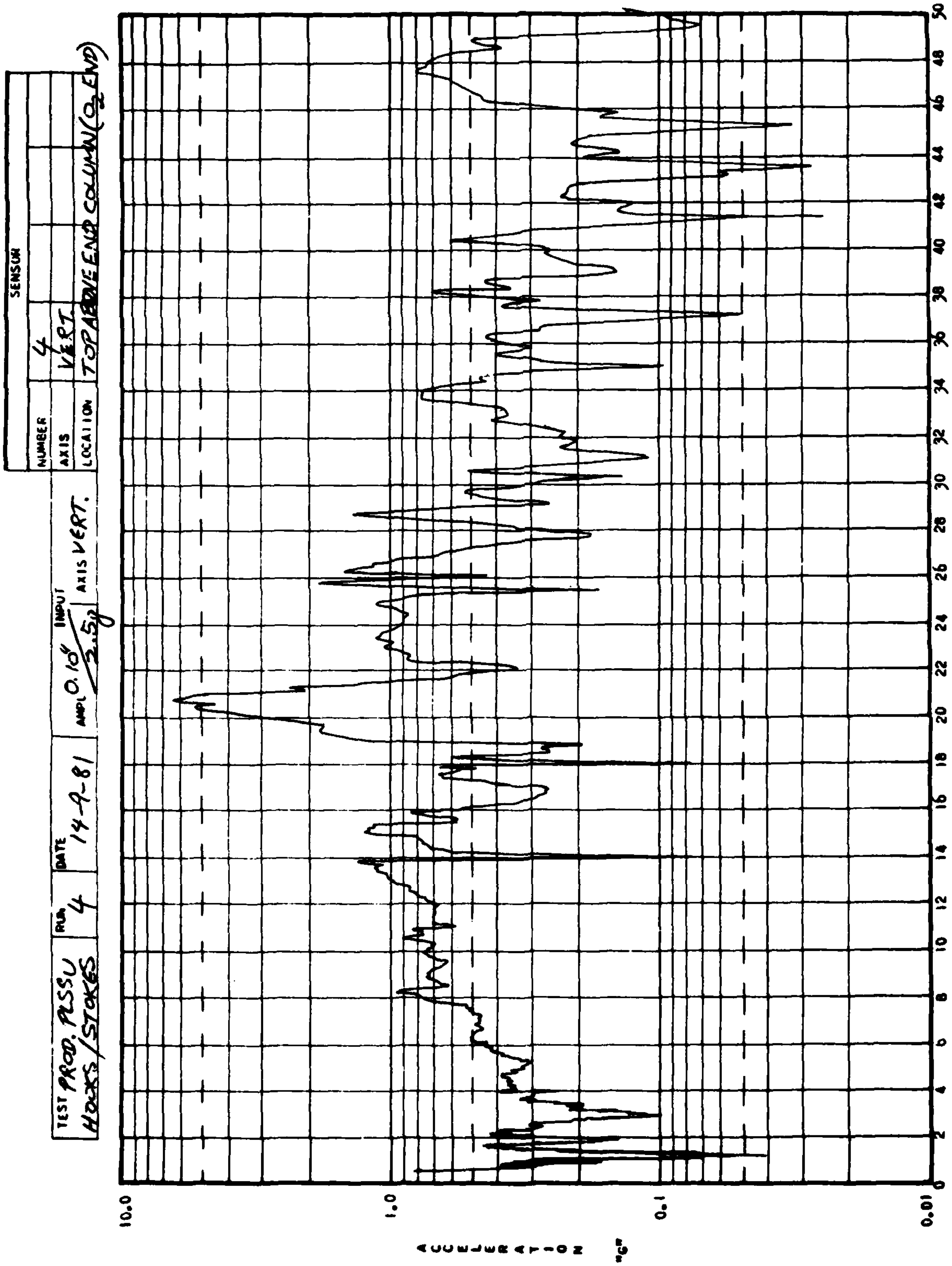

SENSOR
NUMBER 1
AXIS VERT
LOCATION TOP OF MAIN BEAM, NEXT HANDLE
TEST PROD. PLSSU STOKES/HOOKS
RUN 4
DATE 14-7-81
AMPL 0.10"
INPUT 2.5g
AXIS VERT.
10.0
1.0
0.1
0.01
ACCELERATION "G"
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
FREQUENCY, HZ

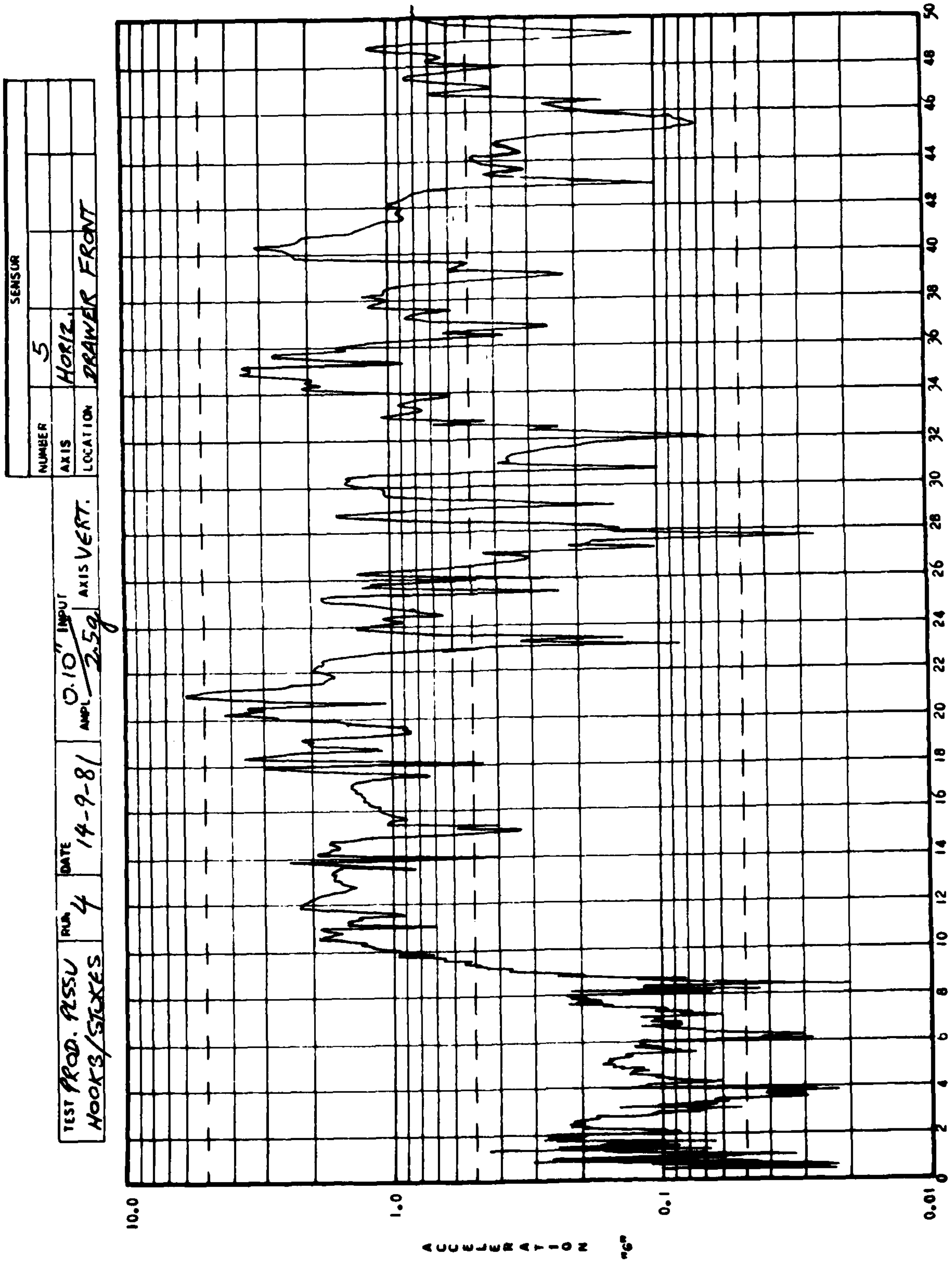

TEST/PROD. PLS.U
MAROKS/STAKES
RUN 4
DATE 14-9-81
AMPL 0.10"
INPUT 2.5g
AXIS VERT.
SENSOR
NUMBER 2
AXIS VERT.
LOCATION MAIN BEAM SY END COLUMN
ACCELERATION "G"
10.0
1.0
0.1
0.01
FREQUENCY, Hz
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50

11ND NOSC 3960/56 (5-77)

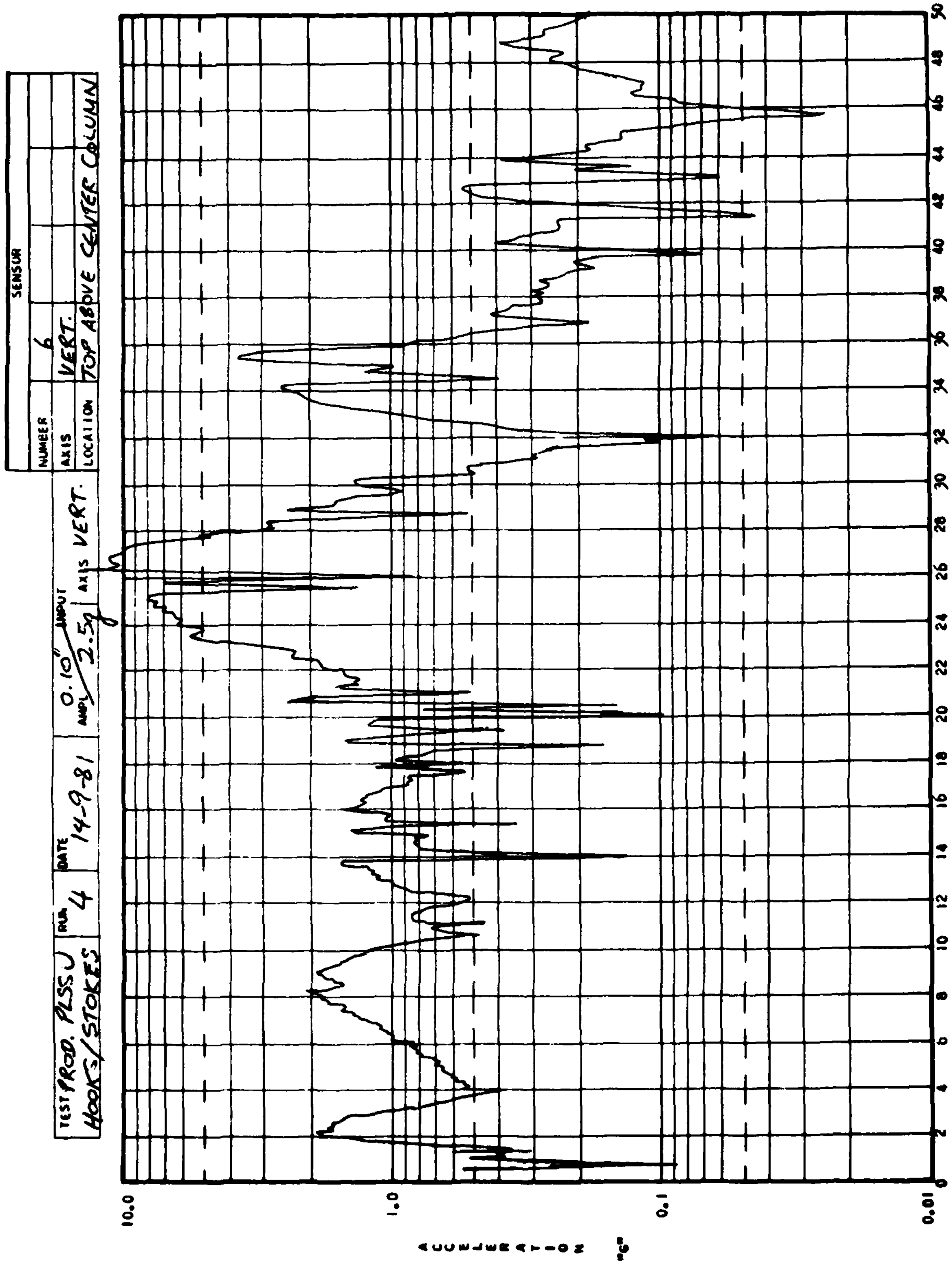


11ND NOSC 3960/5B (5-77)

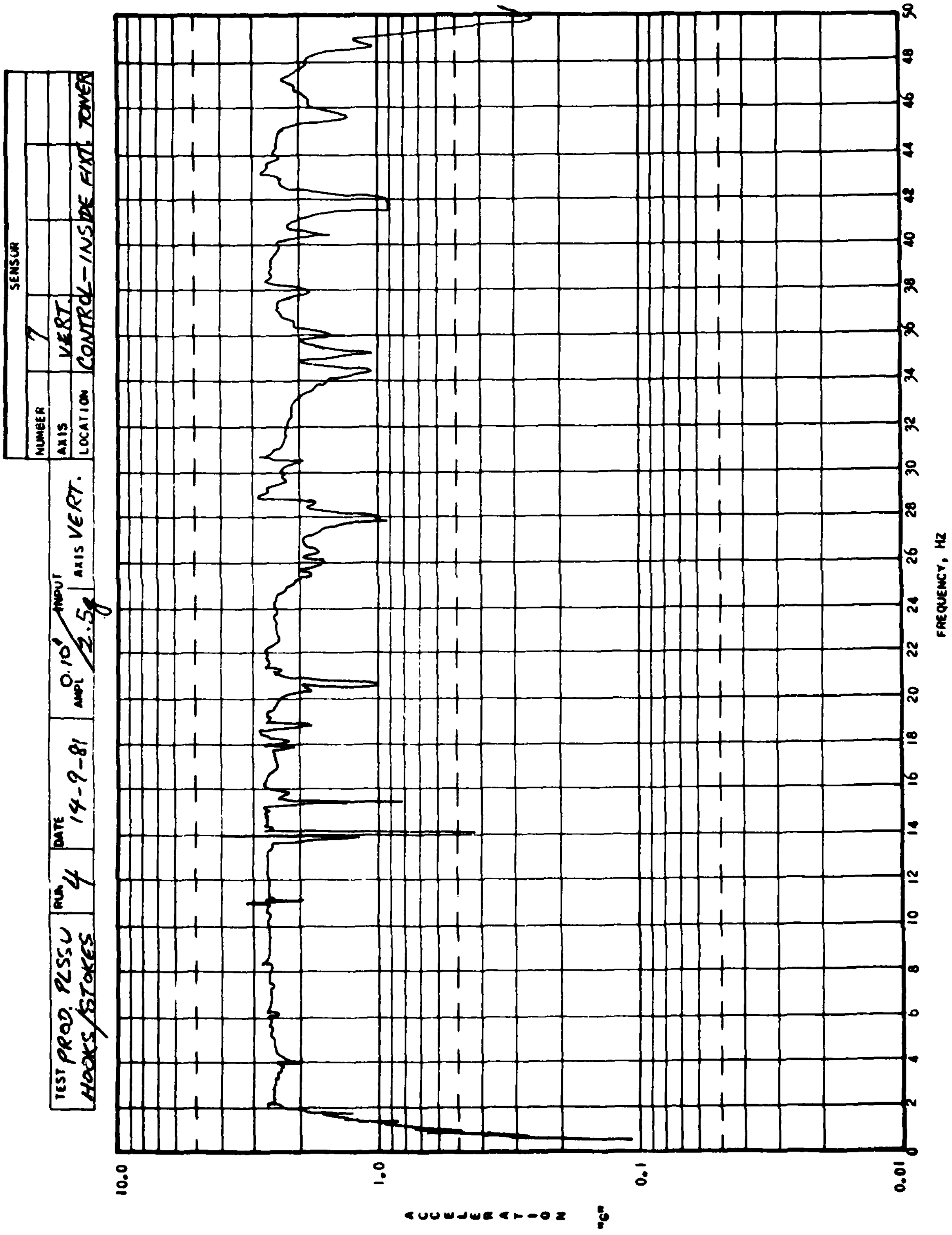


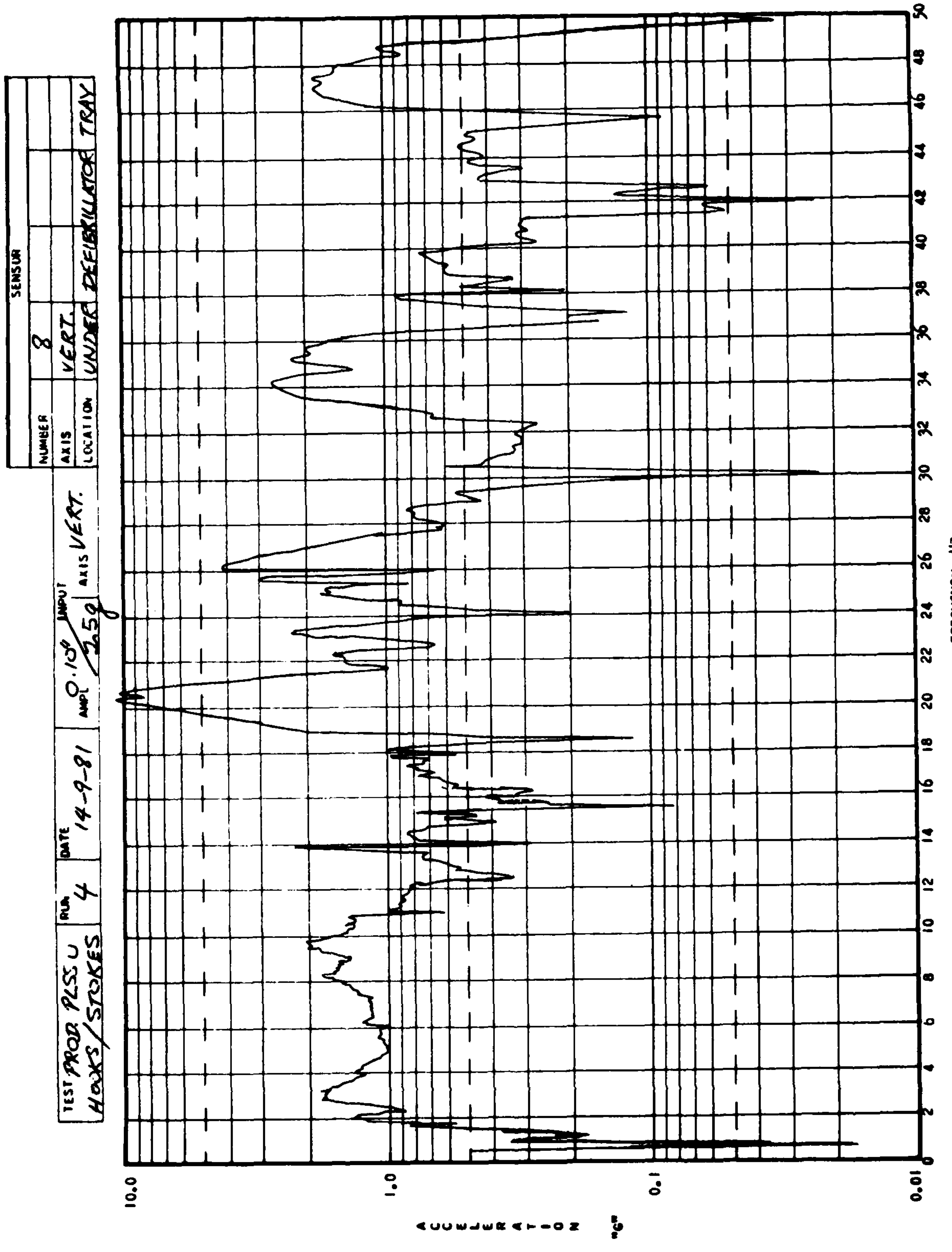

TEST PROD. ASSU
HOOKS/STOKES
RUN 4
DATE 14-9-81
AMPL 0.10" INPUT 2.5g
AXIS VERT.
SENSOR
NUMBER 5
AXIS HORIZ.
LOCATION DRAWER FRONT
10.0
1.0
0.1
0.01
ACCELERATION "G"
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
FREQUENCY, Hz

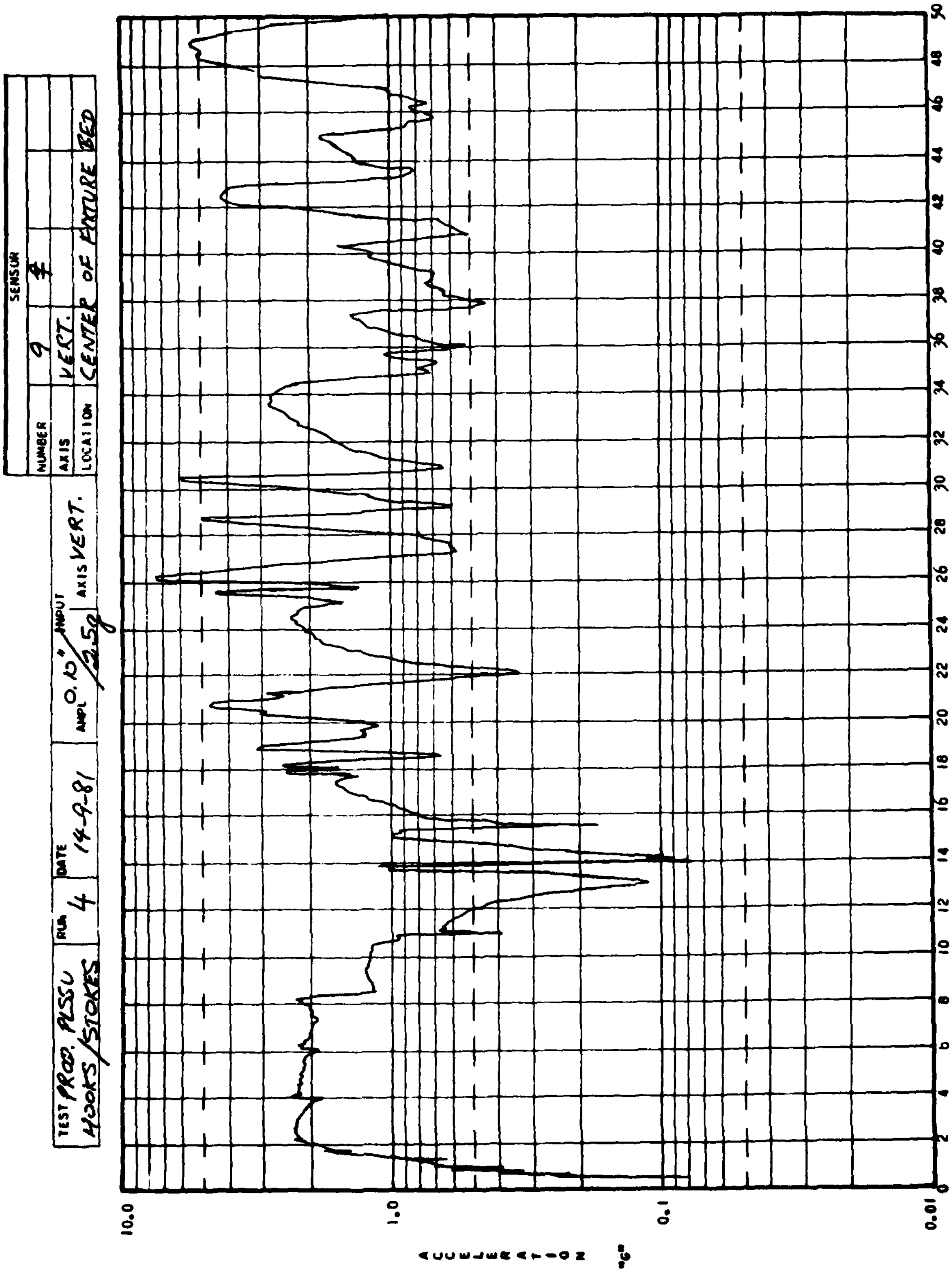
11NO NOSC 3960/56 (5-77)



11ND NOSC 3960/56 (5-77)

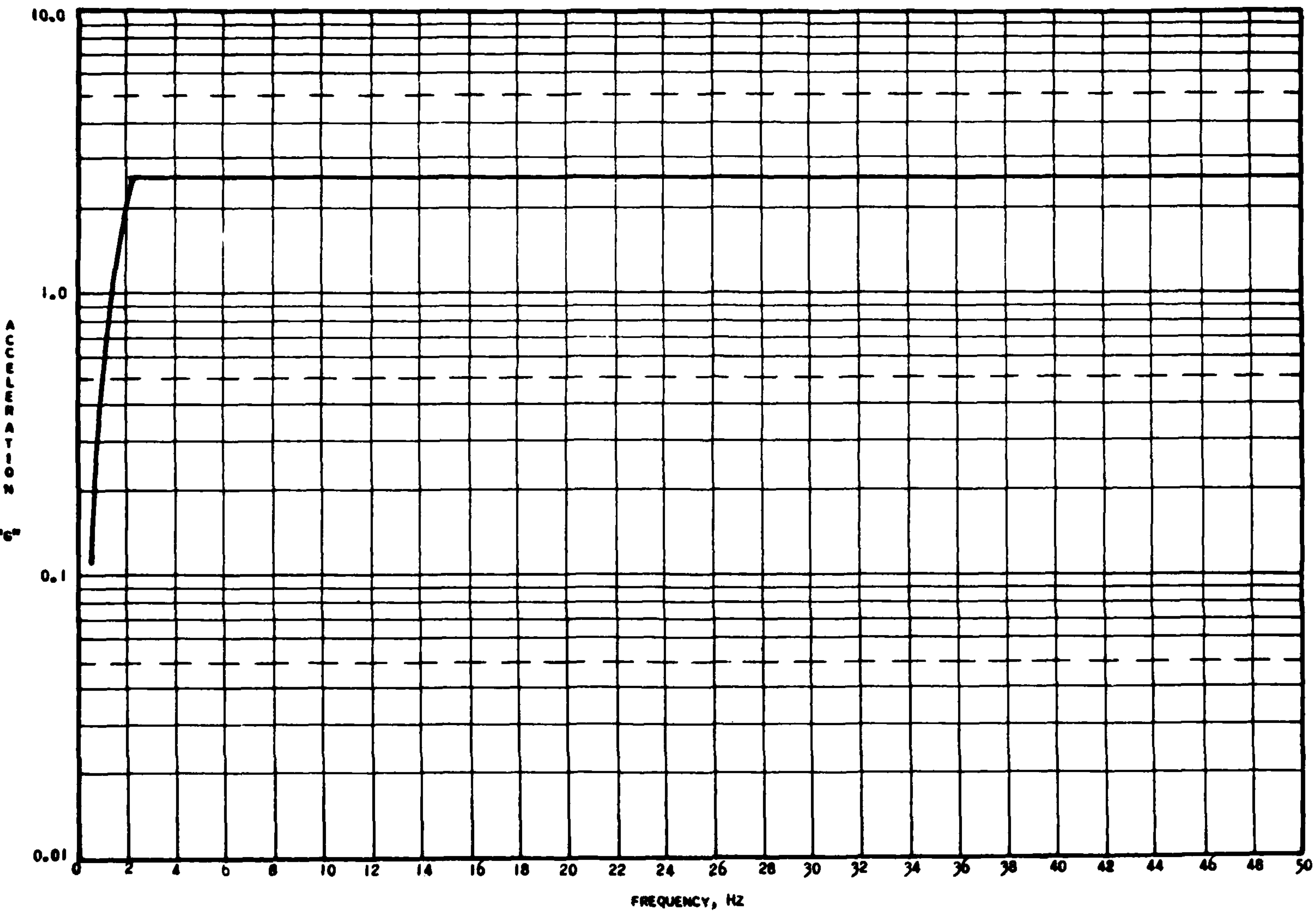



TEST PROD PLSS U HOOKS/STOKES
RUN 4
DATE 14-9-81
AMPL 0.10g
INPUT 2.5g
AXIS VERT.
SENSOR
NUMBER 8
AXIS VERT.
LOCATION UNDER DEFIBRILLATOR TRAY
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
FREQUENCY, Hz
10.0
1.0
0.1
0.01
ACCELERATION "G"



TEST PROD. PLSSU HOOKS/STOKES
RUN 4
DATE 14-9-81
AMPL 0.12"
INPUT 2.5g
AXIS VERT.
SENSOR
NUMBER 9 4
AXIS VERT.
LOCATION CENTER OF FIXTURE BED
ACCELERATION g's
10.0
1.0
0.1
0.01
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
FREQUENCY, HZ

TEST	RUN	DATE	AMPL	INPUT	AXIS	SENSOR	
PLSSU IDEAL TEST	ALL	9-81	0.10"	3.5g	BOTH	NUMBER	
						AXIS	
						LOCATION	



END

FILMED

10-83

DTIC